# **Atmosphere and Severe Weather**

## **Chapter 9**

# **Learning Objectives**

### Understand Earth’s energy balance and energy exchanges that produce climate and weather

### Know the different types of severe weather events

### Know the main effects of severe weather events, as well as their linkages to other natural hazards

### Recognize some natural service functions of severe weather

### Understand how human beings interact with severe hazards and how we can minimize the effects of these hazards

# **Energy**

## **Understanding Energy is fundamental to understanding severe weather**

## When we experience **severe weather**, we need to remember there is a **large amount** of **energy** being **expended**

## There are **three types of Energy**

### **Potential – stored energy**

### **Kinetic – energy of motion**

### **Heat – energy of random motions of atoms and molecules**

# **Heat**

# Heat Transfer

## **Conduction**

### ***Conduction* relies on temperature differences,** causing heat to flow through a substance from an area of greater temperature to one of lower temperature. The atmosphere is a bad conductor of heat, where the earth and water a good conductors of heat

## **Convection**

### ***Convection* is the transfer of heat** by the mass movement of a fluid, such as water or air. Physical mixing of heat energy in the atmosphere or water is called a *convection cell*.

## **Radiation**

### ***Radiation* is a wavelike energy** that is emitted by any substance that possesses heat.The transfer of energy by radiation occurs by oscillations in an electric field and a magnetic field are called *electromagnetic waves.*

# **Earth’s Energy Balance**

## The **Earth receives Solar Energy everyday**

### This **energy sustains the Earth**

### **All the solar energy received by the Earth is radiated back into space**

### In the **shift from incoming to out going energy some of the energy changes form**, but it is **neither created nor destroyed**.

## This **Solar Energy** drives the

### Hydrologic Cycle

### Ocean Waves and Currents

### Global Atmospheric Circulation

## **Although the Earth’s energy balance contains several important components, nearly all of the energy available at the Earth’s surface comes from the sun**.

# **Electromagnetic Energy**

## Much of the energy emitted from the sun is **electromagnetic energy**

### This **energy** is a type of **radiation which travels from the sun** to the **earth at the speed of light**

### This energy is described as a **wave**

### Distance between the tops of **two successive waves** is called the **wavelength**

### The various **types of electromagnetic radiation** are **distinguished by their wavelengths**

### **The is called the electromagnetic spectrum**

#### The ***longer wavelengths* include radio waves and microwaves**

#### The ***shorter wavelengths* include X-rays and gamma rays**

#### ***Visible wavelengths* are a small fraction of the spectrum**

# **Energy Behavior**

## **Once the Solar Energy reaches the Earth it is *redirected, transmitted, or absorbed* by the atmosphere, ocean, and land.**

### **100 units of Solar Radiation hits the atmosphere**.

#### Some is *absorbed*

#### Some is *reflected*

#### Some is *radiated*

### **Total units *radiated out are100 units***

## **Albedo**

### **The *reflective value of an object***

#### The higher the **Albedo value** the *more radiation the object reflects.*

## The **atmosphere is heated by *Earth radiation*** rather than the sun radiation.

# **Basic Heating & Cooling Processes in the Atmosphere**

## **Radiation or Emission**

### The process by which ***electromagnetic energy is emitted from an object***

#### **The hotter the object the *more radiation it emits***

## **Absorption**

### The **process of *electromagnetic waves by striking an object***

#### **Different objects have *different absorption abilities***

## **Reflection**

### The **ability of an *object to repel electromagnetic waves without altering either the object or the waves***

## **The *relative amount of energy reflected or absorbed is important in determining the temperature of the air and land***

## **Scattering**

### The **act of deflecting or redirecting light waves** with gas molecules and particulate matter in the air

### ***Rayleigh Scattering*** – when the **shortest wavelengths are scattered (violet and blue)– causes the “blue sky”**

### ***Sunset or Sunrise***– **all the blue waves scattered as the energy passes through a longer atmosphere (larger angle) red, orange, and yellow left**

# **The Atmosphere**

## **Gaseous envelope that surrounds the earth**

### Made up of **gas molecules, suspended particles of solid and liquid, and falling precipitation**

### **Causes all the weather we experience**

### Responsible for **trapping the heat that warms the Earth enough to be habitable**

### Knowledge of the **structure and dynamics of the atmosphere is critical to understanding severe weather, as well as the mechanism and causes of global warming**

# **Composition of the Atmosphere**

## The main two gases found in the atmosphere are ***nitrogen*** and ***oxygen***

## ***Carbon dioxide*** is next gas found in a small amount in the atmosphere

## ***Relative humidity* is one of the types of moisture found in the atmosphere**

### This is the **most familiar** of moisture measurements

### This ratio compares the ***actual amount of water vapor in the air to the water vapor capacity of the air at a given temperature***

#### **Capacity** is the **maximum amount of water vapor that can be in the air at a given time**

#### As the ***temperature increases*, relative humidity decreases**

#### As the ***temperature decreases*, relative humidity increases**

# **Structure of the Atmosphere**

## ***Thermal layers*** of the atmosphere

### ***Troposphere and Tropopause* -- COLD**

#### **Lowest level**, closest to sea level

##### **11 miles at equator to 8 miles at poles**

##### **Varies with the passages of warm and cold air**

### ***Stratosphere and Stratopause*--WARM**

#### **Extends from 11 miles above sea level to 30 miles above sea level**

#### **Has the Ozone layer within, causes the warming by stopping Ozone**

### ***Mesosphere and Mesospause-*-COLD**

#### Begins 30 miles and ends 50 miles above sea level

### ***Thermosphere*--WARM**

#### Begins at 50 miles and gradually extends out

### ***Exosphere*—NO TEMPERATURE**

#### Outer most portion of the atmosphere

#### Blends with interplanetary space

# Structure of the Atmosphere

# **Weather Process**

## **Four aspects** of the atmosphere **directly related to severe weather are:**

### ***Atmospheric pressure and circulation patterns***

### ***Vertical stability of the atmosphere***

### ***The Coriolis effect***

### ***The interaction of different air masses***

# **Clouds**

## **Clouds associated with severe weather**

## Consist of small **water droplets**

## Classified on the basis of **altitude** (low, middle, and high) and **form**

### **Cirriform** – high thin and wispy and composed if ice crystals – often **proceeds a storm**

### **Stratiform** – appear as a grayish sheets that cover most or all of the sky, rarely being broken up into individual cloud unites – can be associated with the **formation of fog**

### **Cumuliform** – massive and rounded, usually with a flat base and limited horizontal extent but often billowing upward to great heights – associated with **severe thunderstorms and tornadoes**

# **Atmospheric Pressure**

## **Atmospheric Pressure is the force exerted by the gas molecules on some area of the Earth’s surface or on any body**.

## **This pressure is exerted on every solid or liquid surface it touches**

## **It is Omni-directional, exerted equally in all directions**.

## **Atmospheric pressures are simply the “weight” of a column air above a given point**.

## The ***taller the column of air the greater the pressure***

## Air pressure can be on the **surface of the earth or on a plane in the air**

### So at ***sea level, the column of air above is longer thus the air pressure is higher, and the air is denser***

### At a ***high altitude there is a smaller column of air, so the air pressure is lower and the air is less dense***.

### *Nearly all of the weight of the atmosphere and pressure is in the* ***lower atmosphere below the elevation of 31 miles***

## **The decrease in air pressure decreases with altitude but not at a constant rate.**

# **Density of Atmospheric Pressure**

## **Density and Pressure**

### **Density is the mass of matter in a unit volume**

#### The *density of a gas is proportional to the pressure* on it and the *pressure the gas exerts is proportional its density*. ***The denser the gas, the greater the pressure it exerts***.

### ***Atmosphere is held to the Earth by gravity***. So as the *air moves away from the Earth, there is less gravity and less density, thus less pressur*e.

#### ***Higher altitude, less density, less pressure***

#### ***Lower altitude, higher density, higher pressure***

# **Factors Influencing Atmospheric Pressure**

## **Changes in *air temperature* and *air movement*** are responsible for most of the horizontal variation in atmospheric pressure.

### **Temperature change influences pressure**:

#### ***Cold air is denser than warm air and exerts a higher pressure on the underlying surface***

##### ***The density of cold air is higher because its gas molecules have lower kinetic energy and stay more closely packed together (They’re cold)***

### When ***air pressure and temperature are related, air pressure varies geographically***

### This has a ***strong effect on the weather and global atmospheric circulation patterns***

# **Atmospheric Circulation Patterns**

## ***Solar heating and evaporation of seawater at low latitudes create warm masses with high relative humidity***

### This creates **low-pressure zones** at equatorial latitudes the convect (move) upward in the atmosphere

### These **zones cool as they rise causing an increase in relative humidity and condensation to form clouds**

### This creates **abundant precipitation characteristics in the tropics**

## Having ***dropped the rain, the dry, cold and dense air spreads out and sinks at 30 degrees north and south***

### **Subtropical middle latitude deserts** are the results of these descending air masses

### These include the Sahara, Arabian, and Mojave deserts

## ***Similar vertical circulation cells are observed at the middle latitudes***

### This creates **low-pressure zones** at the middle latitudes, **30 to 60 degrees north or south**

### These zones cool as **they rise causing an increase in relative humidity and condensation to form clouds**.

### This creates mid-latitude zones of **air masses giving seasonal precipitation**

## Above **60 degrees north and south, are the polar circulation cells**

### These **circulation cells create descending highs of cold air with relatively low precipitation**

## **Air movement can also cause changes in atmospheric pressure**

## An **overall flow of air into or out of a region is described** as

### In the **Northern Hemisphere**

#### ***Low pressures (L) – Divergent -- counter clockwise***

#### ***High pressures (H) – Convergent -- clockwise***

### In the **Southern Hemisphere**

#### ***Low pressures (L) – Divergent -- clockwise***

#### ***High pressures (D) – Convergent -- counter clockwise***

## **Wind Speed – indicates the intensity of the pressure**

### If the ***gradient is steep, the wind speed is fast***

### If the ***gradient is gentle the wind speed is slow***

## ***After looking at all these different patterns, it is easy to see that atmospheric pressure is a major driving force for wind and weather***

# **Buoyancy of Air**

## ***Atmospheric Stability***

### ***Stable air*** –if a **parcel of air resists upward vertical movement**

#### Could become **unstable if a force is applied, such a topographical feature (mountain slope)**

#### ***Stable air is NON-BUOYANT – High Pressure***

### ***Unstable air***– if it **either rises without any external force other than the buoyant force or continues to rise after such an external force has ceased to function.**

#### ***Unstable air is BUOYANT – Low Pressure***

#### **Unstable air continues to rise until it reaches temperature and density equal to itself, this is called the equilibrium level**.

#### ***Unstable air is associated with severe weather, such as thunderstorms and tornadoes***

# **Fronts**

## ***Boundary between a two unlike air masses***

## ***Not two dimensional boundary at the surface, but a three dimensional zone of discontinuity***

## ***Regardless of which air mass is advancing on the other, the warmer air will always be lifted by the colder air mass***

### **Warm, Cold, Stationary, and Occluded fronts**

## Regardless of which ***air mass is advancing on the other, warmer air will always be lifted by the cold air mass***

## Because of the different temperature, the air masses will have different:

### ***Humidity levels***

### ***Wind patterns***

### ***Stability***

# **Warm Fronts**

## Formed by ***advancing warm air***

## **Slope is *gentle, ascends over cool air*, decreasing in *temperature as the air rises***

## Clouds ***form slowly with not much turbulence*** (**High cirrus clouds**, moving towards a **altocumulus or altostratus**

## ***Broad precipitation, protracted and gentle***

# **Cold Fronts**

## Forms by ***advancing cold air***

## Is a ***steeper front than a warm front*** *with a “****protruding nose****”*

## ***Moves faster than a warm front***

## ***Rapid lifting, unstable air, blustering and violent weather***

## ***Vertically developing clouds***

## If ***unstable air, precipitation can be showery or violent***

## ***Precipitation along the leading edge and immediately behind the ground-level position of the front***

# **Stationary and Occluded Fronts**

## **Stationary Fronts** – Boundary ***between the warm and cold fronts***

### May stay ***stationary for a few hours to days***

## **Occluded Fronts** – when the ***rapidly moving cooler air overtakes another cooler air mass and warm air is wedge above the frontal boundary***

## ***Each of the four types of Fronts can cause inclement weather***

# **The Coriolis Effect or Force**

## ***Appearance of all things drifting sideways*** as a result of the Earth’s rotation

## **Why?** If a rocket is shot directly at New York, by the time the rocket arrives at New York, the ***Earth has rotated and the rocket seems to have “drifted”***

## ***Applies to any freely moving object***

# **Four Basic Points of the Coriolis Effect**

## 1. ***Regardless of the initial direction of motion***, any freely moving object appears to deflect to the ***right*** in the **Northern Hemisphere** and to the ***left*** in the **Southern Hemisphere**

## 2. The apparent deflection is ***strongest*** at the **poles** and ***decreases* progressively toward the equator** where there is zero

## 3. The Coriolis affect is ***proportional*** to the ***speed***of the object, so a ***fast-moving object is deflected more than a slow one***

## 4. The Coriolis affect ***influences direction of movement only***… it has ***no effect on speed***

# **Hazardous Weather**

## The ***basic principles of the atmosphere which we have looked at can help us understand associated hazards***

## ***Severe weather*** refers to:

### **Thunderstorms**

### **Tornadoes**

### **Hurricanes**

### **Blizzards**

### **Ice storms**

### **Mountain windstorms**

### **Heatwaves**

### **Dust storms**

# **Thunderstorms**

## **Thunderstorms:**

### ***Three basic atmospheric conditions* are necessary for a thunderstorm to form:**

#### ***Warm humid air must be available in the low atmosphere***

#### ***A steep vertical temperature gradient must exist in the environment***

#### ***An updraft must force moist sir up to colder levels of the atmosphere***

### **Defined as a *violent convective storm* accompanied by thunder and lightning**

### ***Found frequently found in conjunction with other kinds of storms***

### ***Triggered by unstable uplift***

### **Formation called the *cumulus stage***

### ***Mature stage* – in which updrafts and downdrafts coexist as the cloud continues to enlarge** – heavy rain accompanied with hail, blustery winds, lighting, and the growth of the anvil top

### ***Dissipating stage* -- with light rain ending the turbulence**

# **Localized Severe Thunderstorms**

## **Severe Thunderstorms can have**

### ***Wind exceeds 58 mph***

### ***Hailstones larger than ¾ of an inch***

### ***Generates a Tornado***

## **Conditions to create a severe thunderstorm are**

### ***Changes in wind shear***

### ***High water-vapor content***

### ***Updraft of air***

### ***The existence of a dry air mass above a moist air mass***

### ***Most important is the Vertical wind shear***

### ***The most damaging is the supercell storm***

### ***Hailstones can be a hazard from a thunderstorm***

## ***Hailstones-cause more damage than casualties***

# **Hail**

## **Large thunderstorms can produce hard pieces of ice called *hailstones***

## ***Severe thunderstorms produce large hail which is the most dangerous***

## **Start as a small piece of ice in the center of a thunderstorm**

## ***Travel up and down the cloud in the cold, freezing more and more ice around the center***

## **Eventually *gets so heavy that it falls to the ground***

## ***Hailstorms can cause a great deal of property damage***

# **Tornadoes**

## **Very small and localized**

## **Most destructive of all atmospheric disturbances**

## **Most intense vortex in nature , deep low pressure cell surrounded by a violently whirling cylinder of wind**

## **Less than a quarter of a mile in diameter but most extreme pressure gradients known** (100-millibar difference from the center to the edge)

## **Upswept water vapor condenses into a funnel cloud**

## **Advances along an irregular track that generally extends from southwest to northeast in the US**

## **Fujita tornado intensity scale (F-scale) for intensity**

## **Formation – develop in the warm moist unstable air associated with a mid latitude cyclone, along the squall line**

## **Develops out of mesocyclone, but only about half of all mesocyclones formed result in a tornado**

## **More than 90 % of tornadoes happen in the US in Tornado Alley**

# **Blizzards and Ice Storms**

## **Blizzards- *Severe winter storms***

### **Large amounts of falling snow**

### **High Winds**

### **Long lasting**

### **Low visibilities**

### **Extended periods of time**

### **Often whiteouts because of the snow**

### **Cold temperatures**

### **Found across the country, *extremely hazardous in the midland of the US***

### **In the east, they can be called *nor’easters***

### ***Extremely dangerous because of the wind chill***

## **Ice Storms**

### **Prolonged periods of *freezing rain***

### **Develop mostly in the *north side of a stationary or warm front***

### **Three conditions that cause Ice Storms to happen**

#### ***Ample source of moisture in a warm front***

#### ***Warm air uplifted over shallow layer of cold air***

#### ***Objects on the land surface close to freezing***

### ***Everything covered with ice***

### **Often found in the *mid-west or east***

# **Fog**

## ***A Cloud on the ground* – becomes hazardous when it *obscures visibility or if pollutants are added to form smog***

## **There are *four kinds of fog* that can develop. These are:**

### ***Radiation fog*** – results when the ground loses heat through radiation usually at night

### ***Advection fog*** – develops when warm, moist air moves horizontally over a cold surface, such as snow-covered ground or cold ocean current

### ***Upslope fog or orographic*** fog -- by adiabatic cooling when humid air climbs a topographic slope

### ***Evaporation fog*** – results when water vapor is added to cold air that is already near saturation

## The ***foggiest areas in the US are the Pacific, New England and the Atlantic Canada coasts, and the valleys and hills of the Appalachians***

## ***Dense fog contributes to numerous accident, injuries, and deaths each year***

# **Drought & Mountain Windstorms**

## ***Hazards created by wind and lack of rain***

### **Drought**

#### ***Extended period of unusually low precipitation*** that produces a temporary shortage of water for people, other animals, and plants

#### More than ***1 billion people around the world live in arid areas***

##### Contribute to food shortages-causes famine

##### Water shortages

##### Power shortages

##### Decrease in industrial productivity

### **Mountain Windstorms**

#### ***Strong winds, usually in the winter, which blow down the downward sides of mountains***

##### Much like our “***east winds***” when we have a high pressure to the northeast of Utah

# **Dust and Sand Storms, Heat Waves**

## ***Hazards created by wind and lack of rain***

### ***Dust and Sand Storms***

#### Strong windstorms carrying suspended dust causing low visibility for a long period of time

### ***Heat Waves***

#### Prolonged periods of extreme heat

##### Both longer and hotter than the year before

##### Happen under prolong high pressures

##### Responsible for many deaths from 1992 on

# **Human Interaction with Weather**

## Many **natural hazards** are ***clearly and significantly altered by human activities***

### We have seen:

#### ***How land use affect flooding and landslides***

#### ***How deep-well disposal and the filling of large water reservoirs may contribute to earthquakes***

#### ***How bad farming practices of leaving exposed topsoil lead to the dust bowl situations like in the 1930***

#### ***Locating mobile homes in areas subject to frequent high winds and tornadoes increases damages and loss of life***

#### ***Land-use practices in cities can intensify the effects of heatwaves***

#### ***On a larger scale, human interaction with severe weather is taking place through global warming***

# **Linkages with Other Hazards**

## ***Severe weather is linked to other hazards***

### **Flooding , often flash floods**

### **Lightening**

### **Mass land movements**

### **Wildfires**

### **Long-term global climate change**

# **Natural Service Functions of Severe Weather**

## There are some ***natural service functions of severe weather***

### There are ***long term services***

#### ***Lightening from a thunderstorm can start a wildfire, which can revitalize a forest or prairie***

#### ***Windstorms can help maintain the health of forests***

#### ***Ice storms are a natural ecological cycle that increases plant and animal diversity in the forest***

### In the ***hydrological cycle, severe weather are a primary source of water***

### Humans can benefit from severe weather by ***enjoying a lightening show, watching a snowstorm, and watch a tornado chaser in a movie describe how they can be dumb being in the middle of a tornado***

# **Minimizing Severe Weather Hazards**

## ***Severe weather will continue to threaten humans*, because we can’t “fix stupid”**

## **But if we as humans work at it, *we can minimize the damage and loss of life associated with them***

## ***We must be able to predict these events accurately in order to reduce their hazard***

# **Forecasting and Predicting Weather Hazards**

## ***Timely and accurate prediction of severe weather events is extremely important if human lives are to be spared***

## ***Even with improvements in satellite sensors and computer modeling, we still have difficulty forecasting severe weather***

## **The *behavior of these events are unpredictable***

## **Many of the new ways to *forecast and predict* the weather have become more and available:**

### **The *use of the Doppler Radar*** stations are used to predict severe weather

### ***Watches and Warnings*** are posted for severe weather-if followed there can be less damage and loss of life

### All of these ***new prediction abilities*** can predict the severe weather, but humans have to be aware of their surroundings and act accordingly

# **Adjustment to the Severe Weather Hazard**

## ***Although we can’t control the weather or the climate, there are two ways we can reduce the loss of life and property***

### These actions include both long-term changes to community infrastructure and plans or procedures to be implemented for severe weather

### Long-term actions to prevent or minimize death, injuries, and damage is considered ***mitigation***

### Establishing community and individual plans and procedures to deal with impending natural hazard is considered ***preparedness***

### **Mitigation activities**

#### ***Using safety-conscious engineering in building structures***

#### ***Installing warning systems***

#### ***Establishing hazard insurance***

### **Preparedness and Personal Adjustments**

#### ***Establishing community and individual plans and procedures to deal with an impending natural hazard***